computing the product of a first complex number and a second complex number, or of computing the product of the first complex number and the complex conjugate of the second complex number. A control signal determines which result the multiplier produces. The multiplier could be modified to provide both products, in which case the computation of one product could use the values computed for the other.

As with the multiplication complexity reduction due to decomposition in fast Fourier transforms, the complexity reduction of the extension of the multiplier in US Patent 4,354,249 suggested above depends on the properties of complex number values in Cartesian coordinates. The complexity reduction also depends on a special relationship between the output products. The complexity reduction does not depend on special properties of finite-precision numeric formats or on special properties of number representations in particular finite-precision numeric formats.

Signal processing transforms such as discrete Fourier transforms, inverse discrete Fourier transforms, and other transforms that compute sums of products are widely used in areas such as digital communications and sonar, radar, speech, image, biomedical, and video signal processing. Whether or not a particular transform is or is not practical depends in large part on the economic cost of building a device to compute the transform and on technological limitations. Many transforms rely heavily on the basic operation of multiplication for signal manipulation. Techniques for low-complexity multiplication and for reducing the number of required multiplication operations are very useful in enabling practical signal processing systems.

The disadvantages of prior art multipliers used in signal processing transforms and of prior art fast techniques for certain transforms are the following:

a. A general multiplier which can compute any of the desired products in a signal processing transform and also other products may be very costly to implement, particularly in technologies such as application-specific integrated circuits, field-programmable gate arrays, and general purpose microprocessors.

b. A constant multiplier which can compute any of the desired products in which one of the numbers is equal to a known constant may have very low individual cost, but also very low flexibility, so that many different constant multipliers may be required for a particular signal processing transform.

c. Prior art non-constant, non-general multipliers have greater flexibility but greater cost than constant multipliers, and at the same time have lower cost and lower flexibility than general multipliers, yet still compute one product at a time separately from other product computations.

d. Using constant multipliers, existing low-cost multiplication operations for special number values and representation formats, or non-constant, non-general multipliers in a signal processing transform reduces the complexity of multiplication operations, but not the number of multiplication operations.

e. Prior art techniques for fast computation of discrete Fourier transforms and other transforms exploit special relationships among the number values of the transform weights when computing in Cartesian or real coordinate systems, but do not exploit special relationships among the particular representations of those number values in particular finite-precision numeric formats.

f. Prior art techniques for multipliers that can produce multiple outputs exploit special relationships between the desired outputs when computing in Cartesian or real coordinate systems, but do not exploit special relationships among the particular representations of the multiplier inputs in particular finite-precision numeric formats.

SUMMARY

The present invention is a technique used in signal processing transforms that compute sums of products, involving multipliers that share intermediate computation results.

Objects and Advantages

Accordingly, several objects and advantages of the present invention are that:

a. Using said invention, computation of two or more products together can be accomplished with lower cost than if each product were computed separately.

b. Said invention can be applied to general multipliers, to constant multipliers, to non-constant, non-general multipliers, or to combinations of multipliers, resulting in a reduction in the overall cost of computing a signal processing transform.

c. Said invention can be applied to signal processing transforms with fixed, known weights, such as discrete Fourier transforms, discrete cosine transforms, discrete sine transforms, and inverse transforms corresponding to each of these, resulting in reduced computational cost.